Emerson response to CEC Request for Additional Information and Questions dated May 20, 2015

May 21, 2015

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Emerson Network Power

CEC Request for Additional Information

- Simulation/input files (for each climate zones) for both the standard and proposed designs
  - Provide May 27th
- Custom curve assumptions
  - Provide May 27th
- Data center size used in the analysis (I am assuming 60,000 sqft, based on 20w/sqft and 1200kW)
  - Based on Customer case in SFO at 1200kW, 85w/sqft, 14,000sqft
- Electronic copy of the “End Use Summary Comparison” spreadsheet
  - Will provide today
- EnergyPlus report (for each climate zone) showing annual hourly energy use (both std/proposed)
  - Provide May 27th

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CEC Questions

Responses on the Following Slides

1. How does AHRI 1360 rate your system?
2. What is the efficiency of your DX system?
3. How does this technology apply to small, medium and large data centers?
4. Should there be a minimum and maximum data center size for this technology?
5. What is the assumed water economizer pump, fan power while in full economizer mode?
6. Assuming an integrated water economizer, what is the assumed pump, fan power while in partial economizer mode?
7. How many hours does a water economizer operate at full economizer mode? Partial? At what temperatures?
8. Besides percentages, how many hours does a refrigerant economizer operate at full economizer mode? Partial?
9. How can R410 be more effective than water as a working fluid (as a liquid) to absorb heat when the specific heat of R410 is 0.43 Btu/(lb F) to water's 1 Btu/(lb F)?

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Q1 & Q2 - AHRI 1360 and Efficiency of the DX

- Test Standard – Rates an air-cooled system at 75F DB, 52F DP return air and 95F ambient
  - NSenCOP = SCOP = NSCC (kW) / Input Power (kW)
- Certification / Verification of performance

DSE Model	SCOP	Min SCOP per Title 20
DA080	2.71	2.1
DA085	2.43	2.1
DA125	2.82	1.9
DA150	2.61	1.9
DA165	2.44	1.9

- Note that this at only one rating point and not a representation of the annualized performance with economization
- Liebert Rating System (LRS) output performance is what the AHRI certification rating are based on

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Q3 & Q4 - Technology application Min or Max Data Center Size

- Currently we have models from 80kW to 165kW. Additional capacities in the floor mount configuration down to 40kW and in a row based cooling unit to 20 kW
- Can apply to any size data center from small to large (~50kW to over 10MW)
- Current installation in data centers from 100kW to 2MW suites (at total site of 10MW)
- Maximum limitation comes down to total TCO analysis based on the site and application

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Q5 & Q6 - Water Economizer Pump and Fan Power assumptions

- Will be provided with modeling file
- Auto sizes with load and ambient temperatures

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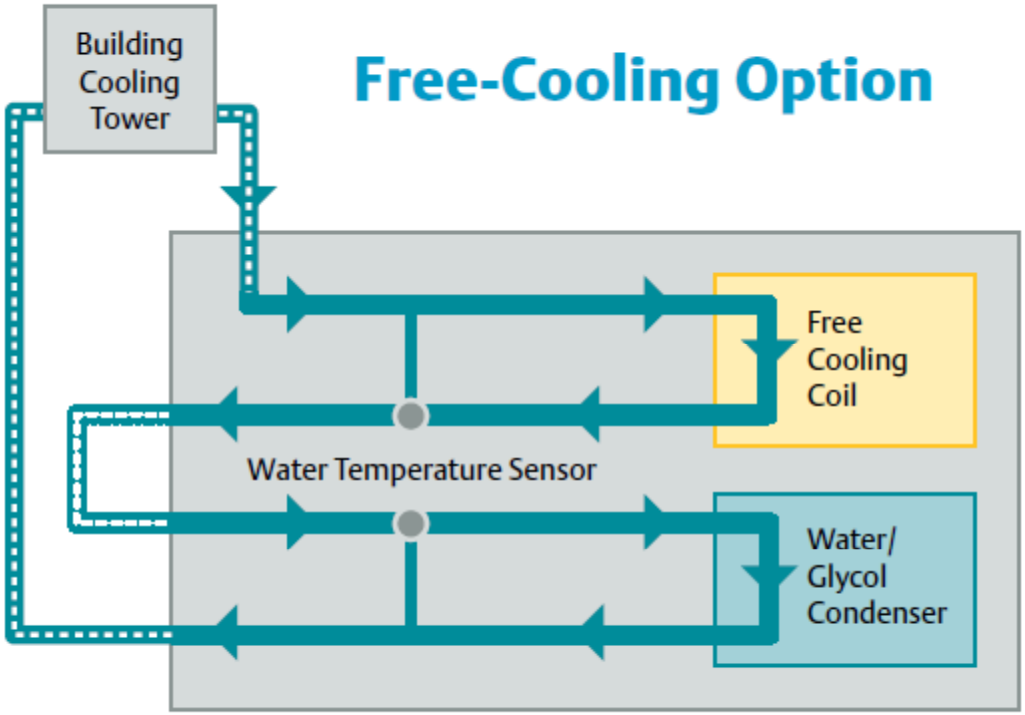
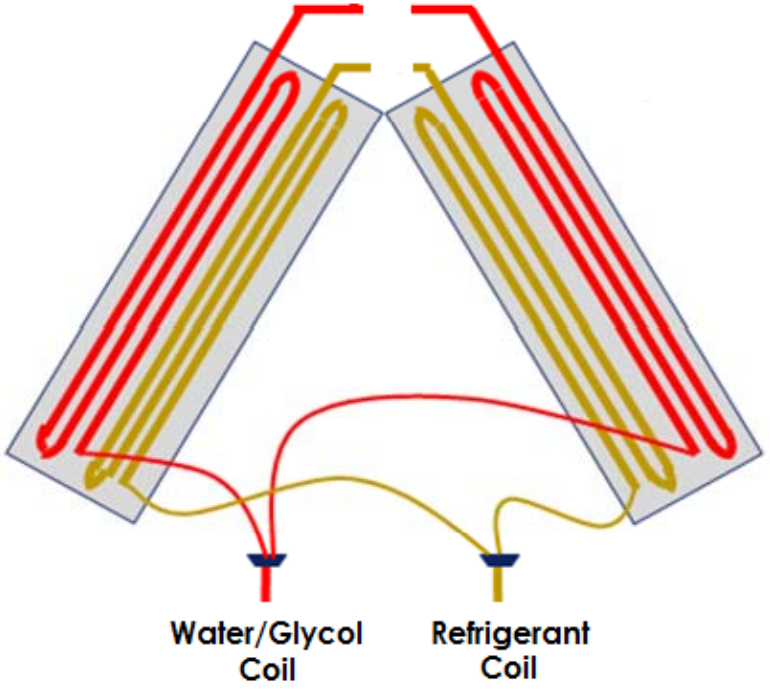
Q7 - Water-Cooled DX with "Free Cooling"

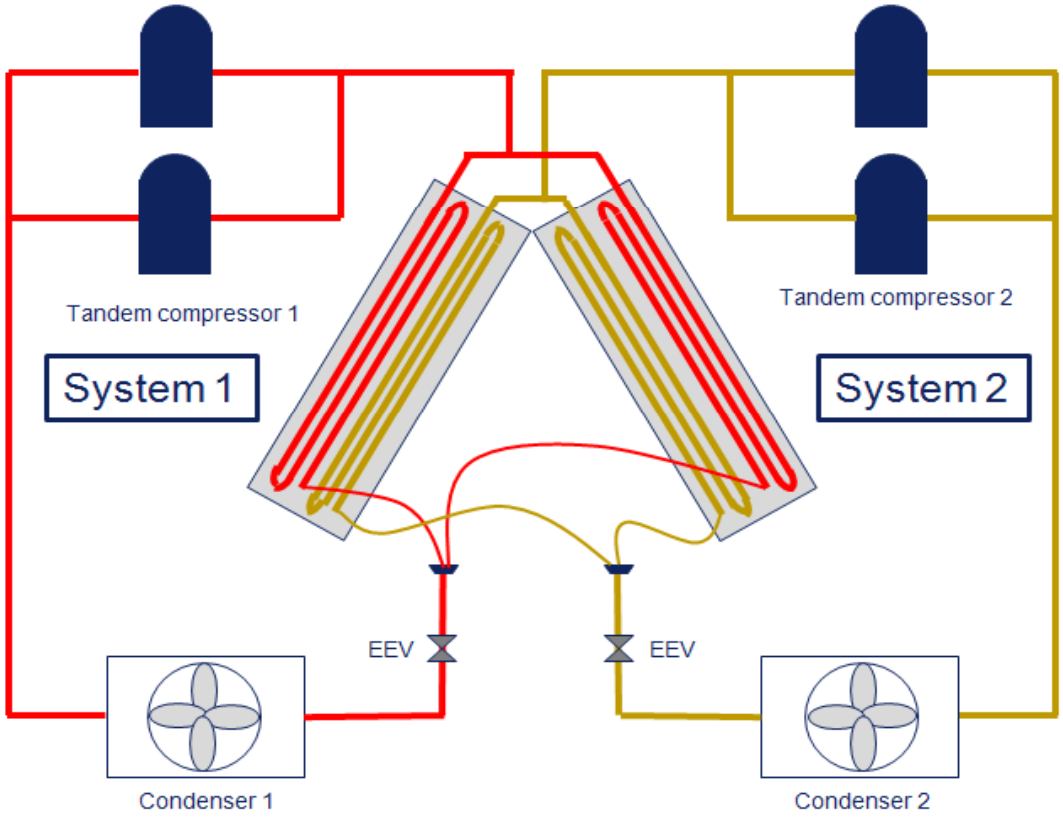
- Can operate with drycoolers, building chilled water, or cooling tower water
- Capacity depends on approach temperature





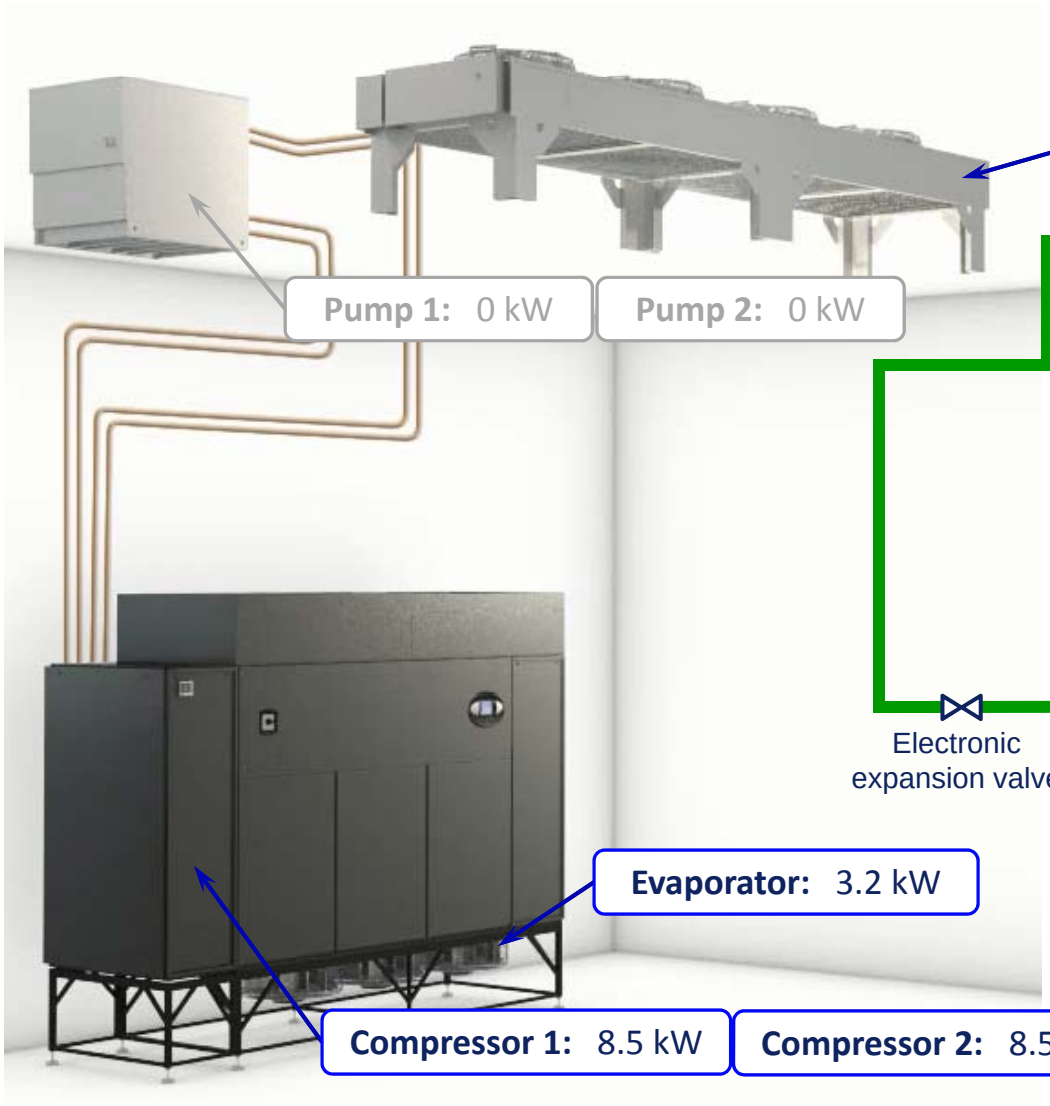
Q8 - Pumped Refrigerant Economizer

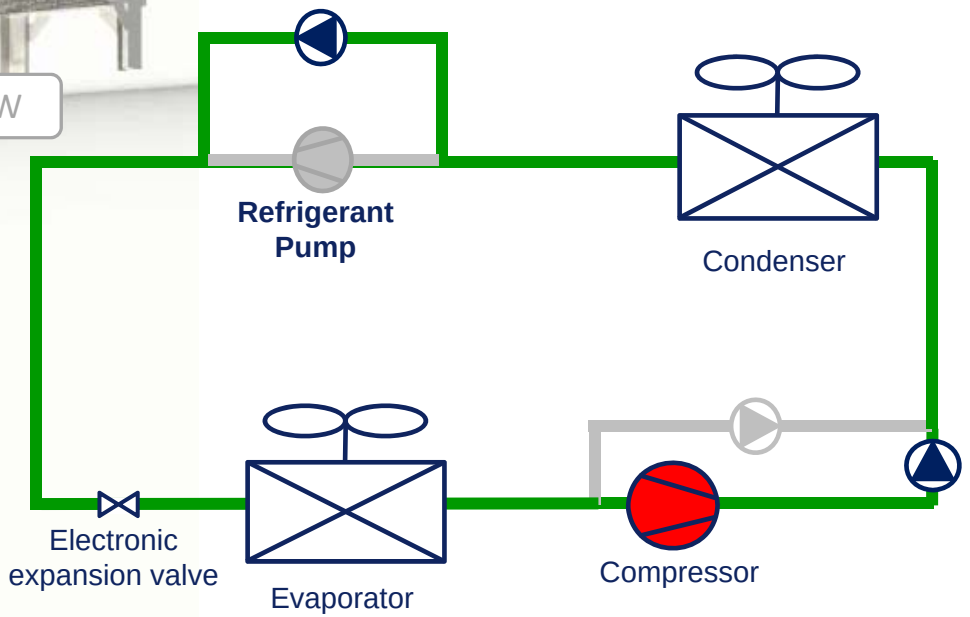
- Independent refrigeration circuits in staged arrangement
- No added air-side pressure drop in either mode
  - At part-load, both circuits active at decreased capacity
  - Two circuits running at reduced capacity provide greater heat transfer surface and increase efficiency



Q8 - PRE System: DX Mode

Cooling Mode	Outdoor Temp	Cooling PUE
Full Compressor	95	1.28





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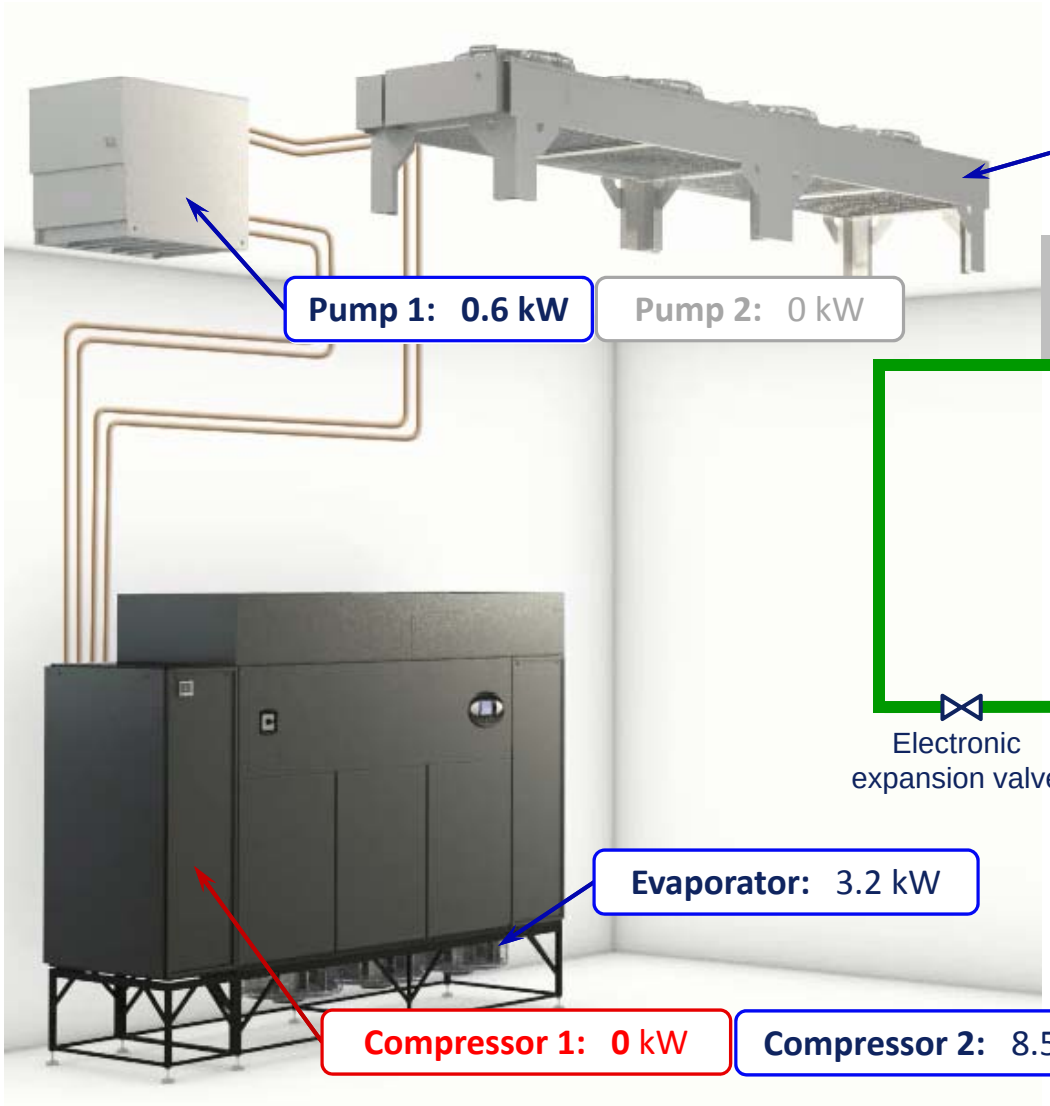
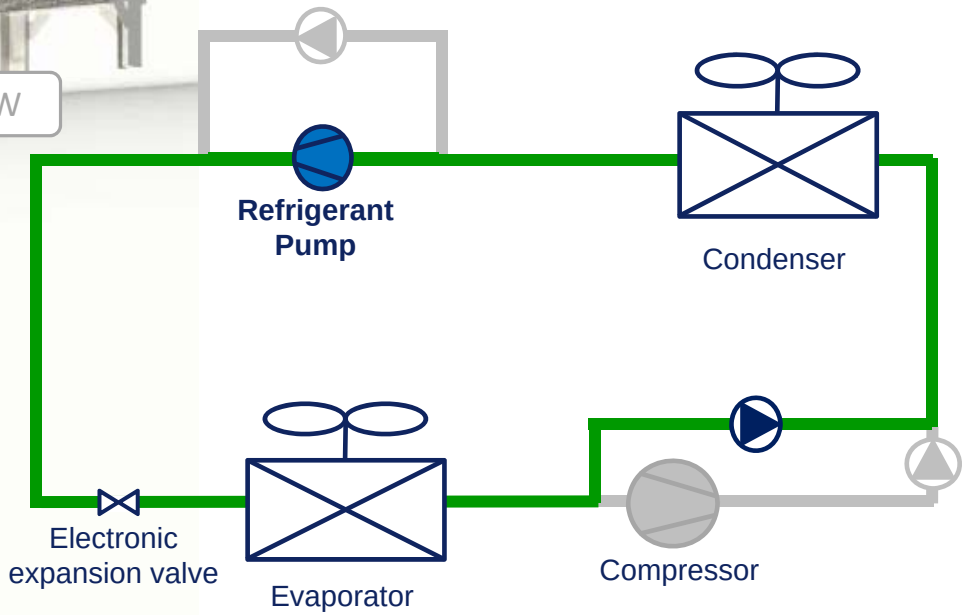
Q8 - PRE System: Partial Economizati

Cooling Mode	Outdoor Temp	Cooling PUE
Full Compressor	95	1.28
Partial EconoPhase	75	1.17





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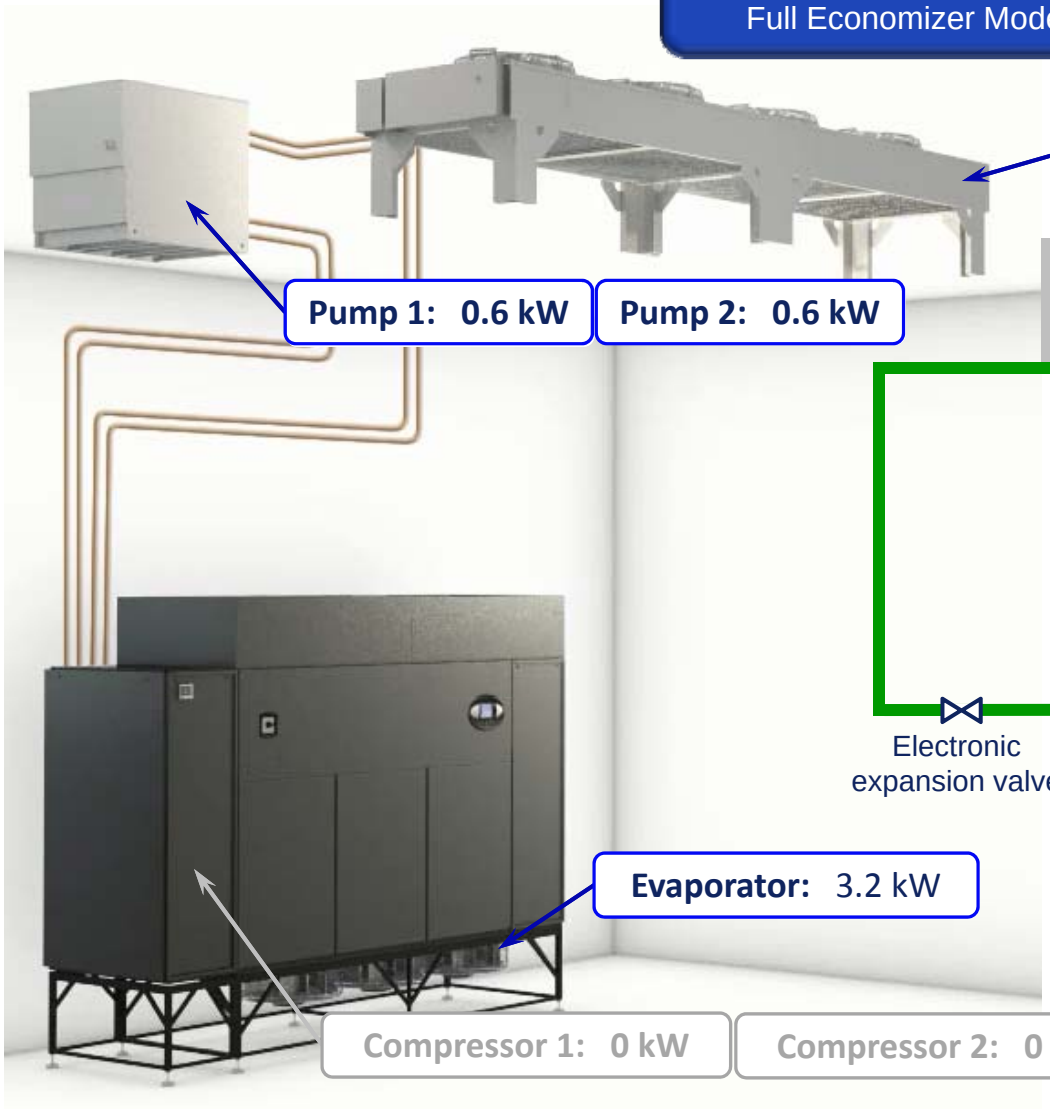
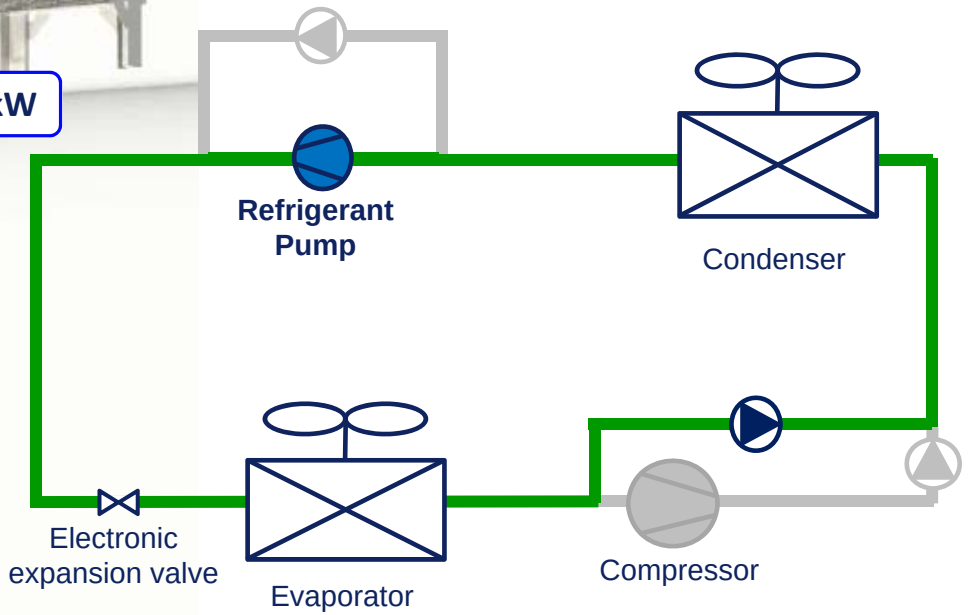
Q8 - PRE System: Full Economization

Cooling Mode	Outdoor Temp	Cooling PUE
Full Compressor	95	1.28
Partial EconoPhase	65	1.17
Full EconoPhase	50	1.09

PUE as low as 1.05
Full Economizer Mode





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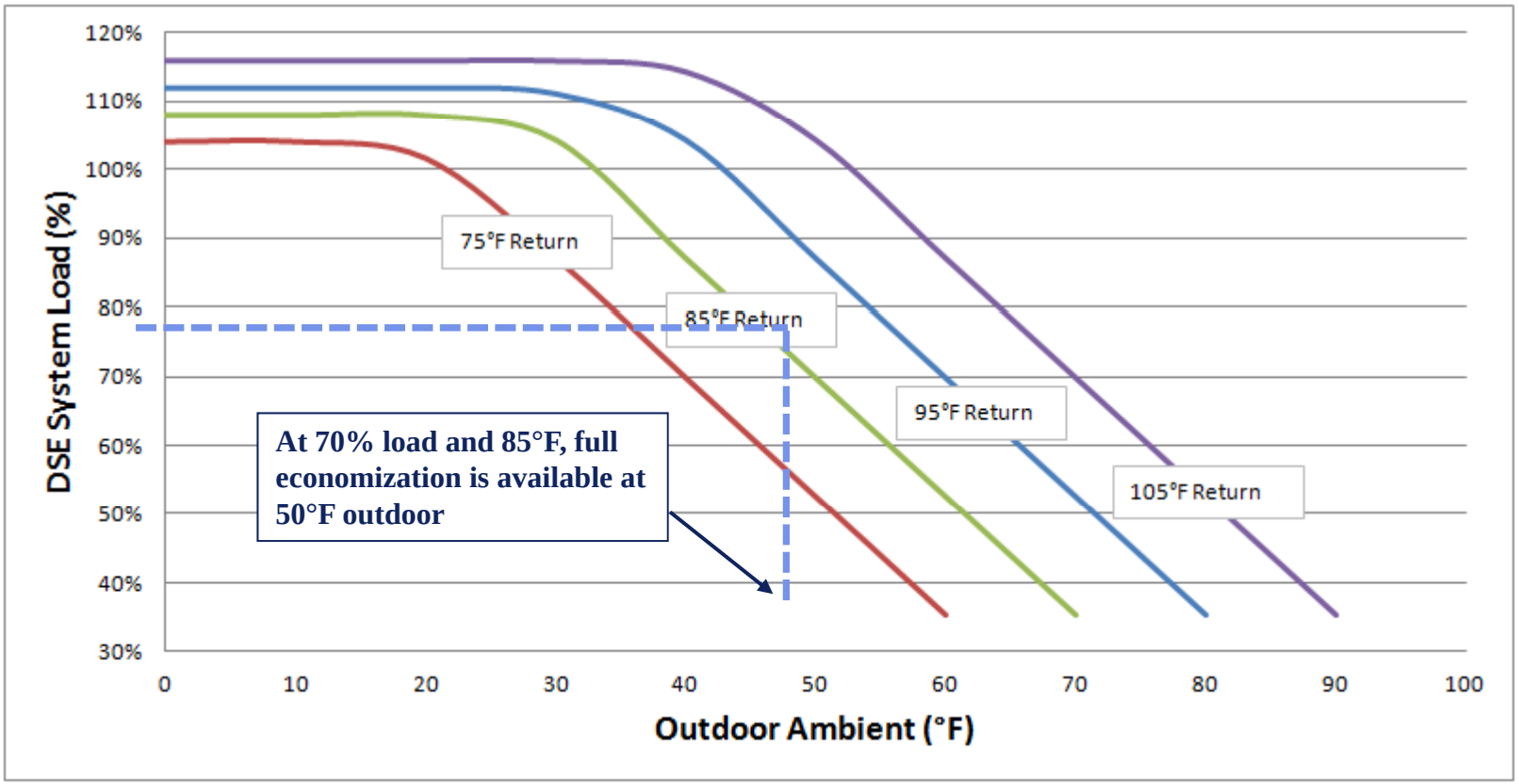
Q8 - Most Efficient System:
Liebert EconoPhase 100% Free-Cooling Capability



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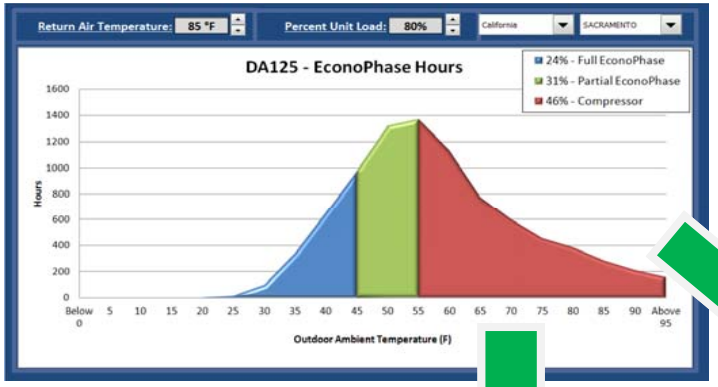
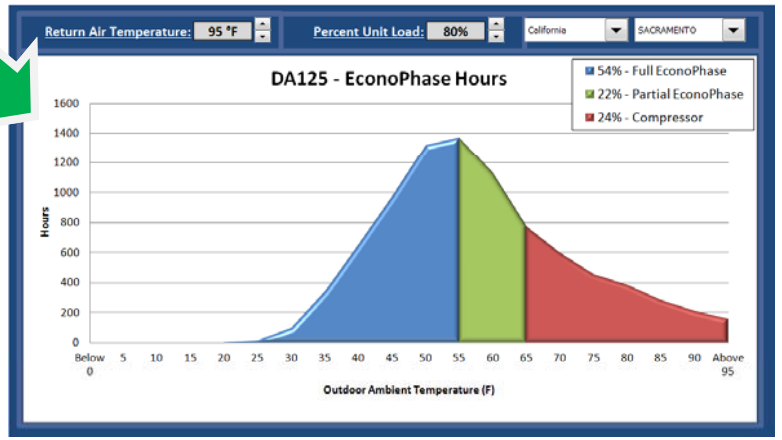
Q8 - Liebert DSE Control to Adjust to More Hours of Economization

- Mix of Full and Partial Economization by Ambient

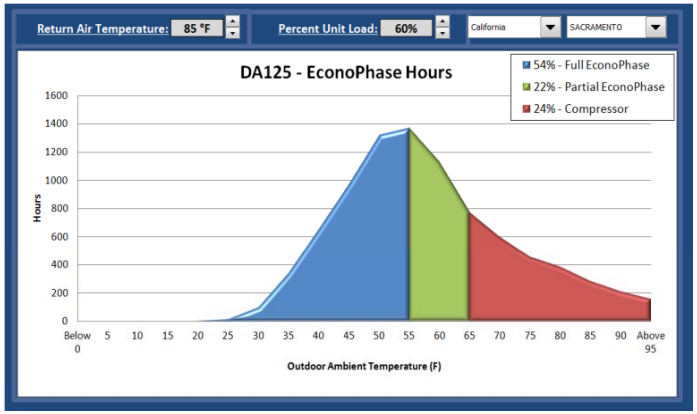
Base Line – RAT-85F/80% load



> RAT – RAT-95F/80% load



< Load – RAT-85F/60% load



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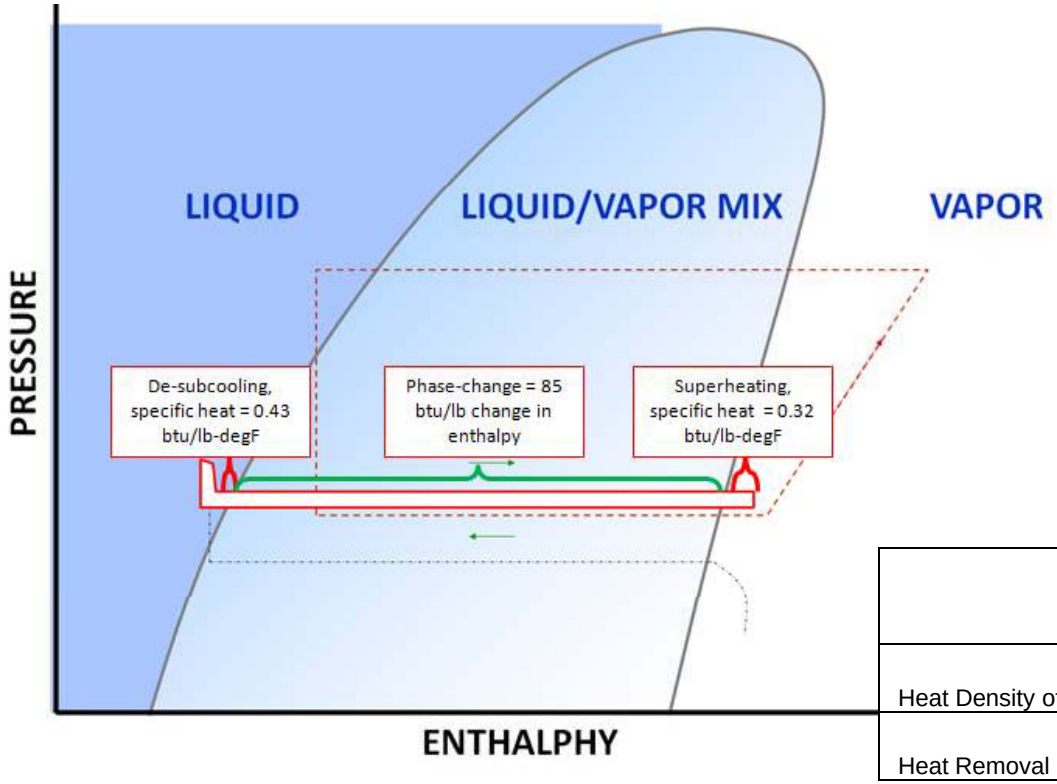
Q9 - R410a Efficiency vs Water

Pumped Refrigerant Cycle

- Unlike compressor operation, the evaporator is the higher pressure side of the system, so the “top” line on the p-h diagram refers to the evaporator
- The 0.43 specific heat mentioned refers to the specific heat of liquid R-410A. This only applies to the de-subcooling that happens in the evaporator, and accounts for a very small percentage of the heat transfer. It is not large enough to even affect the overall heat rejection COP
- The real change in energy occurs through phase-change in the evaporator and then again in the condenser. This change of state represents the 85 btu/lb difference in enthalpy. Note that this is not in btu/lb-degF, because it is happening at constant temperature.
- Finally, there is a very small effect from superheating, as shown. Again, like the subcooling effect, this is a very small enthalpy change.



R-410A has ~3x the heat capacity as water for the same volume. Glycol reduces heat transfer efficiency.

	Air		Water		Pumped Refrigerant	
Heat Density of Fluid	0.456	btu/ft³	624	btu/ft³	5739	btu/ft³
Heat Removal COP	**30**	**kW/kW**	**364**	**kW/kW**	**1,115**	**kW/kW**

Q9 - Efficiency of Pumped Refrigerant

	Water		R-410A	
Density	62.4	lb/ft^3	67.52	lb/ft^3
Heat Capacity	1	btu/lb-F	85	btu/lb
Volumetric Heat Capacity	62.4	btu/ft3-F	-	-
Typical Heat Rise	10	F	-	
Volumetric Heat Transfer Content	624	btu/ft^3	5739.2	btu/ft^3
Time Period	60	min	60	min
Flow Rate	1	ft^3/min	1	ft^3/min
Heat Transfer per Unit Time	37440	btu/hr	344352	btu/hr
Heat Transfer per Unit Time	10.9698213	kW	100.894228	kW
Typical HVAC Pressure Drop	10	lb/in^2	30	lb/in^2
Typical HVAC Pressure Drop in lb/ft^2	1440	lb/ft^2	4320	lb/ft^2
Input HP per 1 CFM Flow Rate	0.04044444	hp	0.12133333	hp
Input kW per 1 CFM Flow Rate	0.03015942	kW	0.09047825	kW
Heat Transfer/HP	925,714	btu/hp-hr	2,838,066	btu/hp-hr
COP (kW removed / kW input)	**363.7**	**-**	**1115.1**	**-**
Heat Transfer Efficiency	**Base**	**%**	**307**	**%**

Typical COP for Air = ~30

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Q9 - Cost to Move Heat – Economizer Mode